Tertiary wave interactions effects upon large floating structures

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ABSTRACT

Tertiary wave run-up on floating bodies is considered here. Linear potential flow theory is adopted and third-order effects are taken into account through non-linear interactions between incident and diffracted-radiated wave fields, resulting in wave number change of each component due to the interaction with the others. The numerical procedure consists of updating both fields by means of iterations, yielding a steady-state solution in frequency domain. In the present paper, Molin et al. (2005) parabolic model is implemented in a general 3D-BEM seakeeping code, allowing for the assessment of third-order interaction on practical units of general shapes. In addition, the same approach is extended to irregular waves. Results of the presented numerical model are compared to experimental data with both regular and irregular waves. The obtained results show an excellent agreement with model tests, and provide better estimation of wave elevation compared to linear analysis. Thus, bringing this theory into an industrial practice can play a key role in the selection of critical conditions (height, frequency, direction, etc) and structure geometry. As shown in the past, linear and second order diffraction-radiation theories are not always sufficient to explain large measured run-up phenomenon (wave basin or full scale observation). However, other non-linear aspects, such as third-order interactions, can play an important role. They are believed to have significant effects at the first order harmonic quantities (ω) rather than high order harmonics (2ω, 3ω or sum and difference frequencies).

INTRODUCTION

Accurate wave run-up prediction on floating structure is both challenging and practically very relevant to the design of ships and offshore structures. It is a complex phenomenon which depends on both wave conditions (height, frequency, direction, etc) and structure geometry. As a consequence, large relative wave elevation can be seen along the body side leading to green water events. This can result in severe damage of equipments over the deck (piping, cables,) and raise crew safety issues on board.

KEY WORDS: Tertiary interactions, wave run-up, wave-structure interaction.

NOMENCLATURE

For mathematical consistency, vectors are noted in bold characters and || denotes complex modulus. n is the body normal vector pointing towards the fluid domain and ∂/∂n is used for normal derivative. Re is the real part and Im is the imaginary part.

g is the gravity, h the water depth, ρ the fluid density, ω the wave frequency, T the wave period, λ the wavelength, k the wave number, H the wave height, β the incident wave direction, \( v = \omega^2/g \) the infinite-depth wave number.

(D) denotes the fluid domain, (S_b) the body surface, (S_f) the free surface and (S_I) the seabed. (Oxyz) is the body fixed Cartesian coordinates system with (Oz) axis pointing upward and \( z = 0 \) the undisturbed free surface. (OXY2) is the wave coordinates system such as (OX) is the incident wave direction. The transformation relation between the two coordinates system is given by:

\[
\begin{align*}
    x &= X \cos \beta + Y \sin \beta \\
    y &= X \sin \beta + Y \cos \beta
\end{align*}
\]

Finally, assuming time periodic variation, the complex notation is used with the following convention: for a harmonic function \( f \) whose the time domain variation is described by \( f(t) = F_0 \cos(\omega t - \alpha) \), we note: \( f(t) = \text{Re}(Fe^{-i\alpha}) \) with \( F = F_0 e^{i\alpha} \).

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